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Data Visualization: Conversion of Data to Animation Files

by
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FOREWORD

This report details the implementation of some data visualization tools that can be used to convert data files into animations for visualization purposes. It describes the software implementation and purpose of the tool created. This work was done at the Naval Air Warfare Center Weapons Division, China Lake, California, from May to September 2003. It was funded by NAWCWD S&T Software Net discretionary funds.

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13. ABSTRACT *(Maximum 200 words)*

(U) Details of data visualization tools are explored that were developed for the purpose of viewing time dependent data. Because visualization tools are vital to understanding complex physical phenomena, these visualization tools attempt to facilitate converting data into animations that can be saved and used in data analysis and presentation. A User's Guide for the tools is included. The software implementation and purpose are described as well as to how to obtain the software.

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INTRODUCTION

This project was a part of an Engineering and Sciences Development Program (ESDP) tour in the Sensor and Signal Sciences Division, Research Department, Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, California, May through September 2003. The NAWCWD Core Science & Technology Software Network provided funding. This project resulted in a software package that can be used to convert properly formatted numerical data to an animated visualization file. Numerical data files used in this project depicted the time evolution of electric and magnetic fields obtained from solutions of the Maxwell equations with the finite-difference time-domain (FDTD) method.

USING THE VISUALIZATION WIZARD

The Visualization Wizard is a semi-automated wizard tool that creates various types of visualizations. The wizard takes the user through six simple steps to create either an animated movie file from the data or a still image jpeg file, using a small collection of plot types (see Figure 1).

Step 1 – Choose a data file. Press the "Browse" button to select the data file you have. Don't worry about the data format yet. Press the "Next" button to advance to step 2.

Step 2 – Select the data format. Only a few types of data formats are enabled. An example of the selected data format is displayed.

Step 3 – Select a visualization type. You decide whether to make a movie or output a still image. Different options appear, depending on which type you select. Choose a filename for the output, and change or fill in the given fields as desired. If there is only one time-step in your data file, a movie is not very useful. Time-steps begin with "1" as the first time-step (not "0").

Step 4 – Choose graphing options. Here the first time-step of your data will automatically be rendered. Push the "Next Slide" button to advance to other time-steps (this does not affect the creation of the movie or picture later). Select the appropriate

graph options desired (the options are listed below). Once you get your graphing options just right, move to the last step.

1. Graph Types – These are the different plots you can make with this tool.

    a. Contour Plot – The data are contoured by color only (no lines).

    b. Surface Plot – This views the data in a three-dimensional (3-D) mode. Use the "Surface Plot Movement" controls to change the viewpoint through rotations. You can also enable the "Rotate" feature from the "Mouse Functions" to use the mouse to rotate the image.

    c. Cross-Section Plot – This plots a simple cross-section of the data. When you select this plot, a dialog box will request that you enter the endpoints of the cross-section. Only data points between the endpoints along a straight line will be plotted.

2. Surface Plot Movements – These are features for rotating the surface plot and are only valid for the Surface Plot mode.

    a. Elevation – Rotates the image around the axis that forms elevation angles (x-axis).

    b. Azimuth – Rotates the image around the axis that forms azimuth angles (z-axis).

    c. Tilt – Rotates the image around the remaining axis (y-axis). This is similar to elevation on the y-axis.

3. Mouse Functions – These are options for using the mouse in different aspects.

    a. Pointer – Does nothing.

    b. Rotate – This can be used in the Surface Plot mode. By holding down the left mouse button and dragging the mouse, the image will rotate as if the mouse is pulling the image. Ensure that your computer is equipped with a video card or this option will not perform smoothly. If there are a lot of data points, it will also cause not rotate smoothly.

    c. Nudge – This can be used to translate the plot, either up/down or left/right on the screen. (Note that if you rotate your image upside down or backwards, then nudging one direction may move it the other). To nudge, press down the left mouse button, move the mouse, and then release the left mouse button. After you let the left mouse button back up, the image will move. The amount of space the image will translate when nudged depends solely on the value in the increment field.

4. Options – Here are several options for making your image look a better.

a. Zoom – A larger value brings the image in closer, and a smaller value takes it away. It zooms on the center of the display window. The z-component will remain the same.

b. Resolution Color – This controls the color resolution. A larger value will make the color increments smaller, and a smaller value will make the color increments larger. The value of 1 is preset to provide the best resolution for values between –1 and 1. If the colors are faint, try increasing this value. If everything is red or blue, try decreasing this value.

c. Scale – This control makes the z-component larger or smaller. It will not be visible in contour graph mode. If some of the peaks in the surface graph mode are going out of the display window, try decreasing this value. If you cannot see the peaks, try increasing this value.

d. Configure – This button takes the user to a dialog box to configure the scaling values for the scale factor and the color resolution. If known, the user can enter the minimum and maximum values found in the data set. Otherwise the user can have the program run "auto-configure," where the program reads the entire data file to determine the maximum and minimum values. Then the program will automatically determine appropriate scaling values for the scale and color resolution based on those values. Note that this may be time consuming, especially if the data files are large.

Step 5 – Run the output. Press the "Create" button to create the requested output file. If you want to change anything first, you can press the "Previous" button to return to any of the previous steps. When the data file is created, you will be notified.

Step 6 – View the output. Press the "Next" button, and there will be a media player in the window that will begin playing the movie or viewing the image.
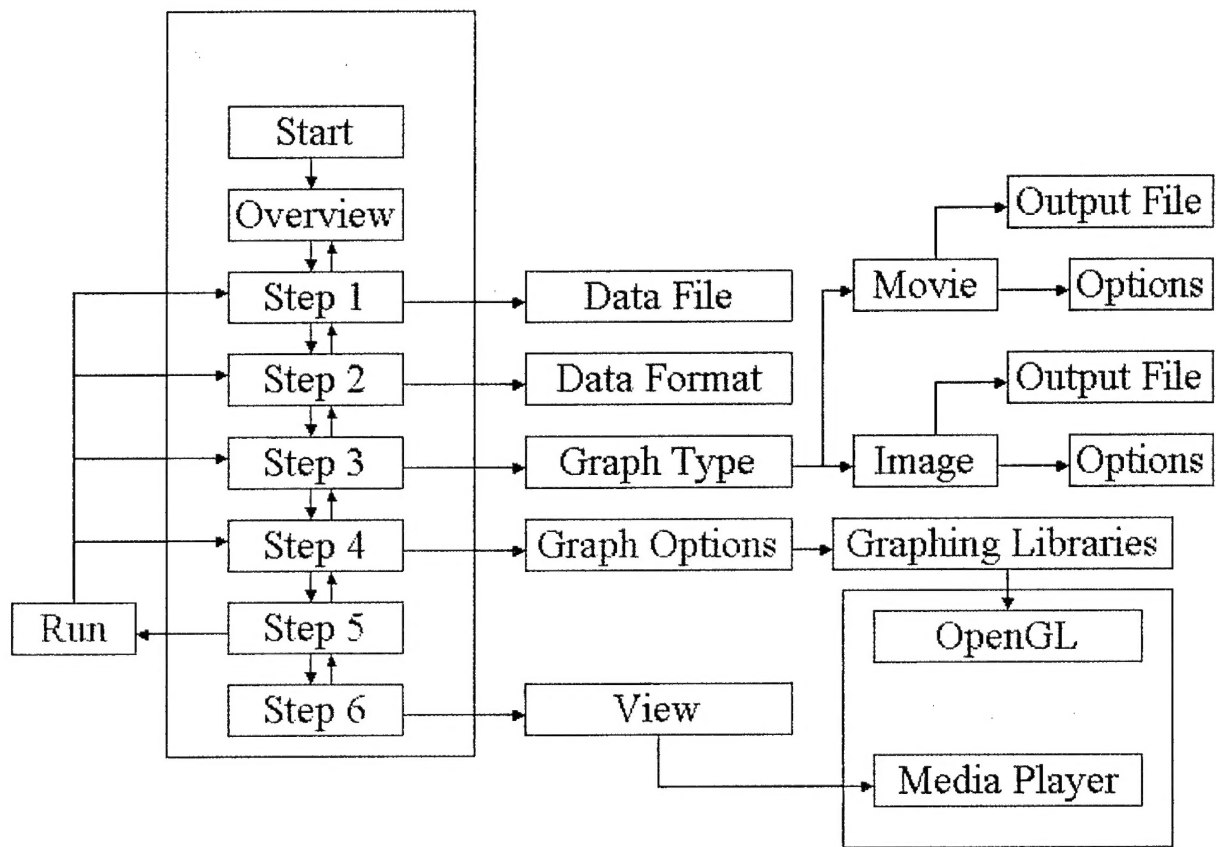
FIGURE 1. Visualization Wizard Flow Chart.

TECHNICAL DETAILS OF THE VISUALIZATION WIZARD

The Visualization Wizard is compiled and written in Visual Studio 7.0 (.NET) utilizing the libraries and functionality of the .NET framework. The .NET framework must be installed on the PC in order for the application to execute (it is a free download from the Microsoft website). The framework is already incorporated into Windows XP SP1 release and all releases thereafter.

The Visualization Wizard can input any of three data formats, two in ASCII format and one in EM Binary data format. There are visual examples of these data formats in step 2 of the wizard.

The first of the ASCII formats will put information into four columns, separated by any white space. The first column will be an integer representing the "x" value, the second column is an integer representing the "y" value, and the third column is an integer representing the "t" value, or time-step. The fourth column contains a real number, which is the value at the given (x, y, t) coordinate in that row.

The second ASCII format will assume the "x" and "y" values. "x" values are assumed along columns, and "y" values are assumed along rows. The data appear in a grid fashion, separated by white spaces and line returns. An empty line separates data from different time-steps.

The EM Binary data format is explained in detail in its own section below.

VISUALIZATION WIZARD VERSUS DATA VISUALIZATION TOOL

The Visualization Wizard and the Data Visualization Tool can both be used to create images or movies from data sets. The Visualization Wizard is easier to use; however it has less functionality. The Data Visualization Tool has more capabilities, including rendering resolution, cross-section overlays, material overlays, and more movie creation options. The Data Visualization tool is harder to use and can only input data in the EM Binary data format. However, there is a converter tool in the Data Visualization Tool that can be used to convert ASCII data formats to the EM Binary data format.

DATA VISUALIZATION TOOL QUESTIONS AND ANSWERS

Q: What is the Data Visualization Tool?

A: The Data Visualization Tool is a software research tool. It is directed toward being used with data sets that represent a time evolution. However it can be used with any data set of points x and y and some value at each point. The data are assumed to be a uniform lattice of points, with the x and y values implicitly assumed. The number of x-points and y-points need not be the same.

The Data Visualization Tool can be used to visualize the data as contour plots, 3-D surface plots, and cross-sectional plots. These can be viewed as either snapshots in time or as animations across time.

The Data Visualization Tool utilizes the OpenGL APIs to graphically render the data

points. OpenGL will utilize the graphics card (if any) installed on the PC to accelerate rendering.

Q: How do I load a data file in text format?

A: The Data Visualization Tool can only read EM binary data file types. However a data file in text format can easily be converted to the EM binary data format. The visualization tool provides a conversion tool to convert back and forth from EM binary data type to text data type. Below are instructions for the converter.

1. Select "Data Convert" from the menu.
2. Then select "Text to EM Binary."
3. The Text to EM binary dialog box appears.
4. Input the text file filename.
5. Enter how many rows, columns, and time-steps are in the text file.
6. If you don't know how many rows, columns, or time-steps are in the file, de-select the appropriate check boxes. The program will determine whether it can parse your text file without that information.
7. Push the "Convert" button.
8. A dialog box appears requesting that you to choose a file to which to save the new EM Binary data.
9. The converter then converts the data (it may take a while).

Q: How to I convert an EM binary data file to an ASCII text file that can be read into Excel, etc.?

A: The Data Visualization Tool also provides a converter to convert an EM Binary data file to a text file. Here are instructions on how to use this tool:

1. Select "Data Convert" from the main menu.
2. Then select "EM Binary to Text."
3. The dialog box for the converter appears.
4. Input the EM binary input filename.
5. If you only want a single time-step to be converted, check the check box and enter the time-step. If the time-step indicated is not valid, nothing will be converted.
6. Push the "Convert" button.
7. A dialog box appears requesting that you to choose a filename for the output text file.
8. The converter then converts the EM binary data file to a text file.

Q: How do I make a movie file from my data?

A: The Data Visualization Tool can create a movie as an AVI file from your data.

1. Import the data file.
2. Select the plot type you wish to use (contour, surface, or cross-section)
3. Set all parameters to the viewing area as you wish them to be in the movie (for example, set the render resolution, color resolution, zoom, drag, material overlay, rendering area, etc)
4. Select "Options" from the menu, then select "AVI Options."
5. Select the parameters in the AVI Options window as desired:

   a. Recording Time – Choose the time step with which you wish to start and end your animation.
   b. Frame Rate – This determines how long each frame or picture is seen on the screen, in milliseconds. A smaller frame rate means a faster movie.
   c. AVI to Display Ratio – This determines whether the movie is smaller, the same, or larger than the display window. To make the AVI size smaller, choose a value greater than one. Choosing two will make the AVI size twice as small as the display. Choosing one will make it the same. And choosing values less than one will make the AVI size larger than the display (resolution will not be preserved). A negative value is invalid.
   d. AVI Window to Capture – This determines which portion of the display window will be placed in the AVI file. Consider the bottom lefthand corner of the display window to be at (0,0) and the top righthand corner of the display window to be at (400,400). This does not shrink or enlarge the image onto the AVI, it just "cuts" it out.
   e. Push the OK button.

6. Now select "Export" from the menu then select "AVI." Choose a filename.
7. At this time, a checkmark appears in the menu under "Export" then "AVI" (check it to see). If you decide you didn't really want to create an AVI file, then just deselect the checkmark in the menu.
8. In the Animation area, push "Play." The AVI file will begin recording when it reaches the time step specified in the AVI Options and will stop and close the AVI file when it reaches the specified end time step.
9. When complete, the AVI movie can be viewed by any program that plays AVI files (Windows Media Player, QuickTime) and is compatible on any OS.

Q: How do I save the image that is currently on the display window?

A: On the menu, select "Export" then "Image." Select a filename and the image will be saved in the JPeg format.

Q: It takes a long time to render the image. How can I speed it up?

A: There are several things you can do to speed it up, each with its own drawbacks.

1. Change the Render Resolution – This changes the number of data points that are actually rendered onto the screen.

    a. On the menu, select "Options" then "Render Resolution."
    b. Select a modulus data point to render. Entering a value of 1 will render all data points, 2 will render every other data point, 3 will render every third data point, and so on. Increasing this number will speed up rendering time but will result in a decrease in the quality of the image.

2. Change the Render Area – If you are viewing only a portion of the whole data set, then you can use this option to skip rendering unseen data points.

    a. On the menu, select "Options" then "Rendering Area."
    b. Select to render all or render a selection.
    c. If rendering a selection, enter the lower lefthand corner coordinate from the data set and the upper righthand corner coordinate from the data set to render. All data points inside the rectangle these two points form will be rendered and all other data points will be omitted. Consider the lower lefthand corner to be (0,0) and the upper righthand corner to be (x-max, y-max).

3. Get a faster computer and/or a faster graphics card.

Q: How do I know where media is located from the simulation while viewing the data in the visualization tool?

A: On the main menu, select "Options" then go to "overlays" and click on "materials." A check box will be placed next to "materials" in the menu, indicating that this overlay has been turned on. Positive index media will be shown in white and negative will be shown in black. This is the extent of the capabilities to determine where materials are located. Materials can only be viewed when in the contour graph mode or the cross-section graph mode.

Q: What different types of graphs are available to view the data?

A: There are three types of graphs available: contour, surface 3-D, and cross-section. You can switch among the graph types by selecting the desired graph type on the main window in the "Graph Type" group box.

Q: How to I specify where the cross-section plot takes the cross-section?

A: On the main menu, select "Options" then "Cross Section." A dialog box appears.

Enter the x and y of the first point (one end) of the desired cross-section. Then enter the x and y for the other end of the cross-section. Then close the dialog box.

If you want to see where the cross section is being taken from, go into the contour graph mode and select the main menu item "Options," then "Overlays," then "Cross Section." A check box will be placed next to the "Cross Section" menu item indicating that this overlay is turned on. A white line indicates where the cross-section is taken from in within the whole two-dimensional (2-D) space.

Q: The colors seem really faint on the plots. How can I brighten them up?

A: If the colors seem faint, the values of the field at those points do not vary much. But the coloring scale can be increased. On the "Options" group box in the main window, there is a "Res Color" field. Press the up button to increase the color resolution.

Q: How do I zoom in and out?

A: On the main window in the group box called "Options," there is a "Zoom" field. The up button zooms in and the down button zooms out.

Q: When I zoom in, how can I move the graph position around so that I can see the edge and not just the center?

A: Use the drag mouse function. This is located on the main window, in the "Mouse Function" group box. Select the drag feature. Now, while in the contour mode or the surface 3-D mode, put the mouse over the image. Press the left mouse button down, and drag up, down, left, or right. The image will be dragged by a given number of cells in that direction from the point of view of the image. The "Drag Inc" field determines how many cells the image will be dragged in that direction. Note that while in the surface 3-D mode, because rotations are possible, dragging the mouse one direction may move the image in an unexpected direction. For instance, if the image has been rotated 180 degrees, dragging the mouse to the left will actually move the image to the apparent right, which is actually the image's left.

Q: How do I rotate the image in the 3-D surface mode?

A: Use the controls for elevation, azimuth, and tilt provided on the main window in the "Surface Plot Movement" group box. Values are shown in degrees.

The elevation changes the elevation angle from which the plot is viewed. Viewing straight overhead is zero degree and is very similar to the contour plot.

The azimuth angle rotates about an axis normal to the flat surface plane.

The tilt angle rotates about the third axis centered on the flat surface plane, similar to the elevation but around a different axis.

Q: How do I export to a text file the data enclosed in the cross-section currently viewed?

A: Under the main menu in "Export," select "Data Cross Section." This allows you to save the current cross-section to a text file.

Q: How do I export just the current data set (the time step viewed) to a text file?

A: Under the main menu, select "Export" then "Data Set." This prompts to save to a filename and exports the data to a text file.

TECHNICAL DETAILS OF THE DATA VISUALIZATION TOOL

PROGRAMMING LANGUAGE

The Data Visualization Tool is coded in C#, from the family of C programming languages. Development occurred using Microsoft Visual Studio .NET version 7.0. The user interfaces are specific to C# and require that the Microsoft .NET framework be installed on that PC (a free download from Microsoft). All graphics utilize OpenGL, code originally written in standard C. However, a C# shell has been placed around the OpenGL APIs in a wrapper class conveniently named "OpenGL." This wrapper also accesses another DLL called "OpenGL.Wrapper." This DLL is written in C and is responsible for setting up the device contexts and bitmaps for OpenGL to use when rendering images.

OPENGL CLASS

The OpenGL class is a C# wrapper around the OpenGL APIs that are written in C. They directly call the opengl32.dll file and the glu32.dll file found in the system directory of windows operating systems. The OpenGL class also calls functions from the OpenGL.Wrapper.dll file, written by Jeff Hilde at the Naval Air Weapons Station, China Lake, California.

OPENGL.WRAPPER DLL

This DLL (written in C) is responsible for setting everything up for OpenGL to use

when rendering images. It also contains the bitmap with the rendered images on it. To show the bitmap to the screen, the GUI code must obtain a handle from this DLL. This is specifically useful because it encapsulates C specific code into a DLL for easy access from C# code.

GRAPHING NAMESPACE

Within this namespace resides the code that is used to draw the graphs, given all the data. Three types of graphs can be viewed using the Data Visualization Tool: contour graphs, surface 3-D graphs, and cross-section graphs. Each of these graph types is a child class of the parent Graph class. Thus polymorphism is implemented here.

All of the graph types have the capability to zoom in and out, as well as be dragged up and down and left and right.

GRAPH CLASS

This is the parent class to the other graph classes. It also controls the colors on all of the graph types. Colors are determined in a step pattern (meaning they are not blended as they approach some value, they just change), but OpenGL interpolates colors between vertices so they do appear to blend slightly.

CONTOUR GRAPH CLASS

This is a child class of the Graph class and is used for graphing contour plots. It also provides the ability to overlay a material footprint, as well as a cross-section overlay, so the user can visually see where the cross-section graph will be taken from.

In all reality, the contour plot is really a 3-D surface plot, seen from straight overhead. However it is not optimized for rotations, etc. The contour plot can be dragged using the mouse, but only in the up and down directions and the left and right directions.

SURFACE GRAPH CLASS

This is also a child class of the Graph class and is used for the graphing of 3-D surface plots. It does not provide capability to overlay footprints.

A couple of controls are supplied to enable tilt, elevation, and azimuth rotations of the 3-D surface plot. Dragging is available for surface plots, but only drags from the original position of the graph.

CROSS-SECTION GRAPH CLASS

This is another child class of the Graph class and is used to graph only cross-sections of data. The cross-section parameters are found under "Options" in the main menu, then under "Cross Section." Only points found between the two points specified are graphed in the cross-section plot. The materials are also shown in graphs in this mode.

EM FILE SPECIFICATION

This file specification enables fast and easy reading and writing of data associated with a single field value from a 2-D FDTD simulation. A header comes first in the file, so that the parser easily knows how to parse the data. The rows and columns fields indicate special dimensions, and the times field indicates how many time steps are included in the file. The data are written in binary without any delimiters. The material information is provided so that the location of the material can be identified.

File Encoding Type: Binary data file

File Extension: "*.em"

File Format:

1. Header
   a. Number of Rows (32-bit integer)
   b. Number of Columns (32-bit integer)
   c. Number if Times (32-bit integer)

2. Material Body
   d. All values for epsilon (32-bit single)
      i. For each Row
         1. For each column
   e. All values for mu (32-bit single)
      i. For each Row
         1. For each Column
3. Field Body
   f. All field values (32-bit single)
      i. The sequence of values is iterated as follows:
         1. For each Time:
            a. For each Row
               i. For each Column
      ii. There are no delimiters

AVI FILE CREATION DOCUMENTATION

The code used in the Data Visualization Tool that creates AVI files was found at **http://www.wischik.com/lu/programmer/avi_utils.html,** which was written by Lucian Wischik in 2002. The source code has no restrictions on use and is free. This code allows a programmer to easily create an AVI file and add the frames to the AVI file. Source code is found in the C file "avi_utils.cpp" and in its corresponding header file "avi_utils.h."

The source code was modified slightly from its original version into a C dynamically linked library (DLL). A shell, "AviShell.cs." was written in C# to access the DLL and to add additional simplicity. This shell mostly hides all of handles within the class instance so all that has to be done is call the following three functions:

1. CreateAviFile(String filename, int framePeriod)
2. AddFrame(Bitmap bmp)
3. CloseAviFile()

The AVI files tend to be large because there is no compression available at this time.

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